Palmerston North City Council

Water Supply Mains Pressure Testing Code of Practice

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Contents

Abbreviations

Abbreviations used in this report are spelled out in the following table.

Abbreviation	**Full name**
ABS	Acrylonitrile Butadiene Styrene. A plastic pipe material with good impact resistance. It has similar properties to modern PVC and is mostly used in treatment plants
DI	Ductile Iron A modern form of cast iron that has similar properties to steel. Typically uses socket joints and has blue or green polyethylene sleeves protecting the outside from corrosion.
DN	Nominal diameter. The "official" diameter of the pipe. The actual diameter may be slightly different due to manufacturing practices and tolerances. DN for most pipe materials is based on inside diameter, but DN for PE pipelines is based on outside diameter.
GRP	Glass Reinforced Plastic A composite material formed of glass fibres in resin. The glass fibres provide strength and stiffness while the resin provides flexibility and holds the fibres in place. Usually used for larger pipelines as a lightweight alternative to steel or ductile iron.
ID	Internal diameter.
MAOP	Maximum Allowable Operating Pressure. The maximum pressure in a pipeline in normal operation, including surges.
OD	Outside diameter.
PB	Polybutylene. A cousin of Polyethylene with slightly better flexibility and temperature resistance than PE. It is mainly used in small bore indoor pipework
PE	Polyethylene The main forms are PE80 (medium blue, mainly used for service lines and submains) and PE100 (dark blue, usually used for larger mains). PE100 is stronger and stiffer than PE80. Water pipes are either all-blue or black with blue stripes.
PN	Nominal pressure of the pipeline. The pressure it is designed to be used at.
PP	Polypropylene A cousin of Polyethylene. It has better temperature resistance and can be stronger and stiffer. It is mainly used in treatment plants.
PVC	Polyvinylchloride A rigid plastic. There are three main forms used for pipelines. PVC-U (**U**nplasticised) is the standard material, PVC-M (impact **M**odified) has additives to improve better impact resistance, PVC-O (**O**riented) is deformed during production to improve strength and crack resistance.
STP	Standard Test Pressure. The agreed test pressure for a pipeline test section.

1 Introduction

This Code of Practice has been developed to ensure that pressure testing of new and repaired water supply pipelines demonstrate that the test section follows best practice and is suitable for service conditions.

2 Objectives

Palmerston North City Council is required by law to ensure that the water supply system is free from conditions that may be hazardous to public health. This includes avoiding leaks and breaks in the system.

The objectives of the Code of Practice are to:

- Ensure that new and repaired pressure pipelines can hold test pressure;
- Ensure that new and repaired pressure pipelines are leak free under pressure;
- Provide confidence in the structural integrity of the pipeline;
- Ensure that the appropriate tests are used.

Health and hygiene is covered in the Palmerston North City Council Disinfection Code of Practice.

2.1 Areas of Application

Installation of new mains and connections.

Reticulation system repairs and maintenance.

2.2 Roles and Responsibilities

All water supply contractors must adhere to the Pressure Testing Code of Practice for all work on the Palmerston North City Council water supply networks.

Approval to work on the network is provided by the Palmerston North City Council and all approved persons are required to attend a water main pressure testing training seminar.

Contractors shall be responsible for maintaining test equipment in good condition, and ensuring that any calibrations and safety certifications are current.

Palmerston North City Council may audit the testing practices to ensure the Code is being followed.

2.3 Reporting

Test results shall be reported to the Council Engineer.

3 General

Palmerston North City Council uses site pressure testing when accepting a new or repaired pipeline for service.

In most cases, success or failure is determined by comparing actual values from the test with a calculated value so some calculation is needed. The calculations are mainly quite straightforward but pre-prepared calculation sheets can be useful.

Traditional pressure tests bring a pipeline section up to test pressure and then close off the pipeline. Any drop in pressure can be put down to leakage. Some tests include a small allowance to cover acceptable minor changes in the system during testing.

Polyethylene (PE) pipelines take time to respond to an increase or decrease in pressure. As a result, the pressure in the pipeline changes over time. Because of this, the pressure change in PE pipelines has to be tracked over time and any water added to maintain pressure has to be recorded. This allows the pressure change due to pipe expansion or contraction to be distinguished from any pressure drop resulting from leakage.

Other plastic pipelines also take time to respond to pressure changes, but the effect is usually small enough to ignore for ABS, PVC and Glass Reinforced Plastic (GRP).

3.1 Purpose of Testing

The purpose of field testing of pressure pipelines is to:

- Identify faults in laying (joints incorrectly installed or pipes damaged);
- Identify faults in construction (tapping bands, maintenance structures, frames and covers);
- Confirm the pipeline will hold the test pressure without leakage;
- Test the installed structural integrity of the pipeline under pressure.

3.2 Stages of Testing

The three main stages of testing are:

- Planning – selecting the test method, the test section and the water source;
- Preparation – fitting end caps, installing thrust blocks if required, filling, allowing to stand;
- Testing – pressurising, measurement and checking acceptability;

After testing the pipeline is emptied, disinfected and reconnected.

3.3 Limitations

Pressure testing is useful but it has some limitations:

- It can't detect every type of fault;
- You usually can't tell where a fault is, only that there is one;
- Careful measurement and timekeeping is needed during the test;

- Site conditions (especially temperature changes) can affect accuracy;
- More care is needed when testing plastic pipelines, especially PE pipelines;
- Design faults, poor construction practice and the state of the rest of the system have to be managed using different processes;
- Pressure testing is not a replacement for good installation practice.

3.4 Safety

Testing a pipeline under pressure is potentially dangerous and needs appropriate care to manage risks of injury and equipment damage. Appendix A includes basic guidelines to consider and some examples of what can happen when things go wrong.

4 Planning

The main points to consider include

- which test to use;
- the test pressure;
- the test section;
- the water source and,
- allowing for site conditions.

4.1 Which Test

Palmerston North City Council uses four standard test methods covering large and small pipelines, and for PE and other materials. These are listed in Table 1 and are described briefly below.

Table 1 below shows the four standard tests used for large test sections and for small test sections, for PE pipelines and for all other pipelines. They are described in more detail in Section 5.

Table 1: Pressure test methods used for Palmerston North City Council.

Material **Size**	**PE**	**Other**
Small (<100mm ID and <1,000m length)	Simple rebound test	Visual test
Large (>100mm ID, or >1,000m length)	Pressure decay test	Constant pressure test

Note that some contracts may require a non-standard test.

A visual test on pipes<100mm ID shall only be undertaken on short lengths of pipelines and quick repairs where other testing methods are not practical. Before a visual test is carried out the permission of the PNCC Engineer shall be obtained.

4.1.1 Simple Rebound Test

This simple test is a useful method of checking relatively short, small diameter PE mains and for small diameter rider mains and service connections. The line is raised to the test pressure which causes the PE to expand. After 30 minutes water is drained off to reduce the pressure to 2 bar. With the pressure reduced the PE will start to contract causing the pressure to increase again. Pressure is monitored at 5 minute intervals.

It is known as the rebound test because the pressure drops off at first and then increases again (rebounds) during the test.

4.1.2 Visual Test

This test is intended as a rapid and practical test for smaller pipelines. Bolted joints (and where possible other joints) are left exposed for testing.

The test section is raised to the test pressure and held there for a minimum of 15 minutes while exposed joints and fittings are visually inspected.

The test result is acceptable if there is no damage to thrust blocks and fittings and if there is no obvious leakage.

4.1.3 Pressure Decay Test

All pipes expand under pressure but PE expands much more slowly than other materials. As the pipe expands, the pressure slowly drops. Measuring the change and calculating the rate at which the pressure decays over time can show if the test section is leaking or not.

This test is used for all PE pipes larger than 100mm ID (>DN125) and on long lengths of pipes (>1,000 m in total including service lines). Any test carried out on replacement water mains shall include all service lines up to the gate valve or the metering point.

Pipe expansion in PE pipelines is strongly influenced by soil support around the pipe, so the standard of backfilling can affect the test result. A long stand-down period is needed before retesting.

4.1.4 Constant Pressure Test

All pipes expand under pressure. Most traditional pipeline materials expand very rapidly and there is little or no further expansion once the test section is pressurised. The test section is held at constant pressure and water is added as needed to maintain pressure. Water added over and above the leakage allowance can be assumed to be due to leakage.

This test is most accurate for rigid materials such as Ductile Iron (DI) and Steel. It can also be used on all types of Glass Reinforced Polyester (GRP) and Acrylonitrile Butadiene Styrene (ABS) and all types of PVC, but the test may be less accurate for these systems and may take longer.

This test is not suitable for PE pipelines which expand enough to affect the pressure during the test.

4.2 Test Pressure

The STP is the System Test Pressure. This should be specified in the contract or test specification.

The following factors are considered when setting the STP:

- design operating pressure;
- expected size of pressure transients;
- PN rating of the pipe and any fittings in the pipeline;
- Changes in elevation along the pipeline.

If the STP has not been specified, the pipe PN rating can usually be used in place of the STP. Care is needed if the test section includes fabricated bends and fabricated fittings (e.g. tees, lobster-back bends, flanges or valves) as these may have a lower pressure rating than the main pipe.

At lower pressures, test accuracy is reduced. Because of this, the STP should not be less than half the PN rating of the pipe, no matter how low the design operating pressure is.

Too much pressure can reduce the life of the pipe by permanently stretching it and the whole test section may need to be replaced. This means that it is important to control the pressure during the test, and especially during the initial pressurisation stage.

Acceptable test pressures are summarised in Table 2 below. Higher and lower pressures can only be used where specially agreed with Council before testing starts.

Table 2: Acceptable pressure ranges for testing.

Test pressure	Component	Acceptable?	Notes
<1/2 PN	**Pipeline**	**No**	**Accuracy is too low at such low pressures. Only used where there is no other choice.**
½ PN to PN	Pipeline	Yes	Lower range of acceptable testing. Accuracy can be reduced at lower pressures.
1.25 x Working Pressure	Pipeline	Yes	Preferred minimum test pressure. Accuracy can be reduced at lower pressures.
1.5 x Working Pressure or 1.25 x PN (maximum test pressure)	Pipeline	Yes	Normal maximum test pressure
1.25 x MAOP or 1.5PN (maximum test pressure)	**Any**	**No**	**High pressure risks damaging components**

PN = Nominal pressure of pipe and fittings

MAOP = Maximum Allowable Operating Pressure for the pipeline. In general, this should not exceed the PN rating of the pipe.

4.3 Test Section

For larger pipelines selecting a good test section may need some skill and judgement and the test section will normally be described in the contract documents.

The main considerations include:

- How much water is needed to fill the test section;
- The elevation of the pipeline along the test section;
- How even the gradient is between top and bottom of the test section.

These are described in Appendix C.

4.4 Site Conditions

Temperature changes cause water and pipelines to expand on heating and to contract on cooling. Pressure drops if the pipe expands more than the water and increases if the water expands more than the pipe.

Traditional pipeline materials need a large temperature change to make a significant difference during a pressure test. However, plastics generally and PE in particular are more sensitive to temperature changes than traditional engineering materials. A 3°C change in temperature can change the pressure enough to influence the test result. Because of this, it is important to reduce temperature variations during the test. In addition, if the water or pipe temperature is >23°C the pressure capability of plastic pipelines can be reduced.

In very hot weather, especially where the pipeline is exposed to direct sun it may be better to delay testing, rather than risk damaging the pipe or having to do repeat tests. In very long hot spells this could mean overnight testing or a few days' delay.

Appendix C includes more information.

5 Preparation

Once the test conditions have been agreed, key points to sort out before starting include:

- ensuring you have the right people;
- ensuring you have the right equipment;
- ensuring you have a suitable water supply;
- ensuring that the pipeline is fully prepared;
- understanding what an acceptable test result looks like.

5.1 People

Palmerston North City Council requires trained people to conduct and supervise pressure tests. A minimum of Level 3 National Certificate in Water Reticulation or equivalent is required.

It is best to have a single person in charge of each test. This is usually a supervisor or foreman. It is also important to have somebody on site who can check and do the calculations. This person could be the person in charge or be helping the person in charge.

The person in charge of the test should be on site throughout the test.

5.2 Equipment

The minimum equipment needed for the four standard tests is largely the same.

- End caps and fittings. Extra temporary bracing for end caps, thrust blocks and anchor blocks may be needed;
- Enough test water of the right quality (potable for potable lines, potable or clean for raw water lines).
- A pump (not too big and not too small);
- Pressure gauge (and preferably a logger);
- Water meter or other measuring equipment;
- A timer with an alarm (most phones are good for this and for taking photos to show the test setup, leaks etc);
- Data loggers and/or record pad.

5.2.1 End caps

The flanges or end caps shall be drilled and tapped as necessary for bleeding air, pressurising the pipeline and monitoring the pressure. Tappings for pressure monitoring should be separate from the water inlet and outlet tapping so that pumping or discharge do not influence the displayed pressure. Standard test caps and manifolds can be useful. Appendix D includes examples of equipment.

End caps must be securely fixed to the ends of the pipeline and properly supported so that they cannot work loose during the test. Any joints that do not have enough end-load resistance against the test pressure need extra support against the thrust generated by the test pressure.

For PE pipelines stub flanges with blank flange plates, mechanical end-load bearing caps that grip the end of the pipe or electrofused caps can be used.

Many end-load resistant fittings for PE pipes rely on a stiffener or insert for their end load resistance, so it is important to check these are provided. Following the assembly instructions is particularly important for larger fittings, where installing the insert can be quite challenging.

5.2.2 Test Water

5.2.2.1 What type of water

Potable water pipelines should be tested with potable water wherever possible. Other pipelines should normally be tested with either potable water or with clean, wholesome water.

Palmerston North City Council does not permit contractors to fill test sections direct from the mains. Instead, tankers are filled at designated filling stations with suitable backflow preventers.

The Disinfection Code of Practice describes how to disinfect pipelines before they are returned to service.

5.2.2.2 How much water is needed

The volume of the test section in cubic metres can be estimated from:

Total test length (in metres) x [ID in metres] x [ID in metres] x 3.14/4

For smaller pipes, multiply the number by 1,000 to get the amount of litres you need.

For example, 200 m of 100mm ID pipe (0.1 m) you can expect to need roughly

200 x 0.1 x 0.1 x 3.14/4 = 1.57 m^3 [or 1,570 Litres]

The amount of water needed to fill and pressurise large and long pipelines can be considerable. If the site is remote, a lot of water may need to be tankered in especially if potable water is needed for testing. For larger pipelines and for sites with no convenient water supply a storage tank may be useful so that you can store water from a previous test for use in the next test section. Test water can also be pumped from one test section into the next to avoid wasting it. Water stored on site may need careful handling and disinfection to keep it clean.

In most cases, potable water used for testing can no longer be considered potable after the first test, although it can still be considered as clean and wholesome unless contaminated during testing or transfer. Disinfection of stored water or water transferred from one test section to another may be possible.

5.2.2.3 Disposal after testing

Discharging large volumes of water into smaller watercourses may need some care to avoid any erosion or damage to the watercourse or natural vegetation that may be present. Chlorinated water will need to be dechlorinated before discharge to watercourses. Dechlorination is covered in the Disinfection Code of Practice.

5.2.3 Pump

The amount of water needed to fill the test section is usually much larger than the amount needed to increase or maintain the pressure. Increasing or maintaining the test pressure also needs better control than when filling a pipeline.

This is particularly important for smaller diameter pipelines or short lengths of pipelines where an over-sized pump could easily raise the pressure too much, which can then require a retest. As pumps with high capacity can be difficult to control when restoring or maintaining the test pressure it can be useful to use different sized pumps for filling and pressurising the test section.

Positive displacement pumps are difficult to control accurately and may need some form of pulsation damping. They are usually best avoided because of this.

5.2.4 Pressure Gauge

Accurate pressure monitoring is especially important for PE pipelines. Gauges and transducers shall have been calibrated within the last 12 months. A second gauge (check gauge) should be used to verify that the main gauge (logging gauge) is reading accurately during the test. The check gauge should agree to within ± 5% of the reading before starting the test.

Pressure gauge and logger requirements are described in Appendix D.

5.2.5 Measuring Equipment

Timing accurate to ± 1 minute or better is needed for pipeline testing. Mechanical timers (e.g. stopwatch) can be used but most modern phones have alarms and are more convenient for taking a whole sequence of readings.

The Constant Pressure test requires the amount of water added or drawn off to be measured so a water meter or measuring jug is needed.

5.2.6 Data Logger or Record Pad

For the simpler tests, a record pad is usually good enough but data loggers can be more convenient.

Pressure logging is strongly recommended to provide a full record of the test. During the acceptance pressure test the pressure should be logged at intervals not greater than 5 seconds. For very long duration tests, it may be necessary to use two loggers and switch them between tests – one to log the initial preliminary pressurisation stage and another for the main test. Alternatively, download and clear the logger and start again for the main test. Logging files should be .csv or .xlsx format for easy reading.

Data loggers need enough power and data storage to record readings at 5 second intervals during the main test. For long duration tests, it can be useful to use two loggers, one to monitor the initial (overnight) pressurisation at longer intervals (typically 30 seconds) and the other to take more frequent readings (5 second intervals or less) during the test. It is also possible to monitor overnight at longer intervals, download the results and clear the logger, then monitor the actual test at shorter intervals.

Even if a data logger is being used, a record pad provides a backup record for the test and allows ongoing checking of the test while it is in progress. You may need to provide this record to Council as supporting evidence of the test.

5.3 Acceptance

It's important to know when a test result is acceptable or not and to understand how and when to do a retest. Each of the four standard tests has its own particular acceptance requirements. Some of these require comparing amount of water added or lost to an allowable loss.

5.4 Before You Start

Prior to the pressure test being carried out the main shall be flushed and if necessary swabbed to thoroughly clean the pipe.

Before starting the test, work through the list below:

1. Check that you have an agreed STP and test method for the test section. This needs to be agreed with the Engineer prior to the pressure test procedure being programmed. A minimum of 24 hours' notice is required to be provided to the Engineer as specified in the PNCC Engineering Standards for Land Development. PNCC staff may wish to witness the test or engage an independent person to do this;
2. Work out the allowable loss (if it is used in the test);
3. Have contingency plans and sufficient equipment on site to deal with any bursts, leaks or other emergencies;
4. Make sure that ALL load-bearing pipes and fittings, bends and end caps are adequately restrained against the testing loads and not just working loads. Most PE pipe joints are end-load resistant in normal service but extra restraint may be needed for testing. Pressure testing against a closed valve should only be undertaken where there is no practicable alternative or when any leakage from the valve can be observed and measured during the test. Cast in situ concrete thrust blocks need time to achieve sufficient compressive strength to resist the test loads;
5. The source of water, storage, pumping, flow and disposal plans are in place. Potable water may need to be dechlorinated before disposal. Re-use of uncontaminated test water may be acceptable, especially for larger pipelines, where agreed in advance with the client;
6. All air valves installed have their isolating valves open for filling;
7. Means for filling and flushing, including any facilities for launching and recovery of swabs are in place;
8. Fill the pipeline and vent as much air as possible prior to testing. For larger diameter pipelines running a foam Polyurethane (PŪ) swab through the main ahead of the fill water is an option to help displace air in the line as well as any debris that may be present;
9. Have all the necessary equipment on site before starting the test. Test equipment needs to be correctly calibrated, in good working order, suitable for the test being undertaken and be correctly fitted to the pipeline. Check that batteries for the datalogger, phone etc are charged and will not run out of power during the test;
10. Keep readable, accurate and auditable records of all tests. Where data loggers are used, the datalogger records on their own may not be sufficient, and record forms help conduct ongoing checks during the test;
11. At the end of the test notify the client contact of the result;
12. If retesting is needed, repeat the checklist for each test.

6 Standard Pressure Tests

Fiver standard pressure tests are used by Palmerston North City Council. These are described below. An additional test (the M5 Reference Test) used on PE pipelines is included in Appendix E. The M5 Reference test is only used for special contracts and for some retesting on PE pipelines.

6.1 Simplified Rebound Test

The Simplified Rebound Test is used for checking relatively short, small diameter PE mains and for small diameter rider mains and service connections.

Smaller PE pipelines have ID less than 100 mm (DN125 or less). Shorter pipelines are no more than 1,000 m long in total including service pipes. This allows a rider main down a typical street to be tested in one go.

6.1.1 Method

The pipeline is filled and allowed to settle so that air bubbles can be released. Allow at least an hour, for this.

The line is raised to the STP (see table 2, Page 6) which causes the PE to expand.

After 30 minutes water is drained off to reduce the pressure to 2 bar. The amount of water drained off is measured.

With the pressure reduced the PE will start to contract causing the pressure to increase again. Pressure is monitored at 5 minute intervals for 1hour. The test can be extended to a maximum of 90 minutes if the result is not completely clear after 60 minutes.

It is known as the rebound test because the pressure drops off at first and then increases again (rebounds) during the test.

6.1.2 Acceptance

The test result is acceptable

- if there is no damage or displacement of thrust blocks and fittings and if there is no obvious leakage;
- the pressure rises quickly at first and then stabilises.

If the pressure rises at first and then falls there is probably a leak

If the pressure never rises there is either a leak or air in the line.

Allowable loss is not used in this test.

6.2 The Visual Test (M8 in AS/NZS 2566.2)

This test is intended as a rapid and practical test for smaller pipelines. This method shall only be used at the discretion of the Engineer and shall only be in cases where standard tests are impractical

Smaller pipelines have ID less than 100 mm (DN100 or less). Shorter pipelines are no more than 1,000 m long in total. This allows a rider main down a typical street to be tested in one go.

6.2.1 Method

All bolted joints should be left exposed for testing. It is also useful to leave other mechanical joints and electrofused joints exposed where possible.

The line is raised to the test pressure and held at the pressure for a minimum of 15 minutes while exposed joints and fittings are visually inspected.

6.2.2 Acceptance

The test result is acceptable if there is no damage or displacement of thrust blocks and fittings and if there is no obvious leakage.

6.3 Pressure Decay Test

The pressure decay test is used for PE pipelines that are too big for the Simplified Rebound Test. It is similar to the M6 Pressure Decay Test in AS/NZS 2566.2 but has some minor differences and is simpler.

It is based on the assumption that a pressurised PE pipe keeps expanding under load. As the amount of water in the pipeline is constant, the pressure drops as the pipe expands. Tracking the pressure drop over a few hours can show if there is a leak.

6.3.1 Method

The pipe is filled and allowed to stand (usually overnight). Any air is bled off.

Pressurising the pipe should take 5 to 10 minutes. Less than 5 minutes makes it difficult to get accurate enough readings, and more than 15 minutes will make the test take too long. The test duration is based on the time taken to pressurise the test section so accurate measurement is important from the start.

The test section is pressurised. The time taken to reach the STP is the Loading Time TL and the starting pressure is PL. Measurement times for the rest of the test are based on TL.

- Measure Time T1 and Pressure P1 immediately after reaching the STP.
- Measure Pressure P2 at T2, where T2 = 5 x TL
- Measure Pressure P3 at T3, where T3 = 12 to 15 x TL

Calculate N1 and N2 where

- N1 = (Log P1 – Log P2)/ (Log T2 – Log T1)
- N2 = (Log P2 – Log P3)/ (Log T3- Log T2)

N1 and N2 are calculated using logs. If you aren't familiar with using logs, a standard spreadsheet can be used as long as it has been agreed by the client beforehand.

6.3.2 Acceptance:

The result is acceptable if

- Time to pressurise TL is 5 to 10 minutes
- N1 and N2 are 0.04 to 0.12, and

For an initial check you can check N1 and also check how N2 and N1 compare:

- N1 <0.04, there is probably air in the line
- N1 >0.12, there is probably a leak
- N1 >0.25 there is probably a big leak
- N1/N2 <0.8 there is probably a leak.

N1 and N2 are influenced by the soil support. They are usually within these ranges.

- 0.08 to 0.1 for unsupported pipes
- 0.05 to 0.08 for intermediate ground support
- 0.04 to 0.05 for well compacted fill

Allowable loss is not used in this test.

If the result is unacceptable, the minimum time between repeat tests shall be 4 x the total test time (so approximately 60 x TL).

6.3.3 Issues

It can be a slow test and retesting requires a long stand down time.

High levels of soil support can slow or stop expansion of the pipe.

Air in the pipeline can maintain pressure even when water is escaping.

The acceptance checks for this test require quite a bit of calculation. A calculation sheet can be used provided it has been checked for accuracy and agreed before testing.

You may be need to use a non-standard tests for retesting.

6.4 The Constant Pressure Test (M4 in AS/NZS 2566.2)

The constant pressure test is suitable in all diameters for most pipeline materials. It is based on the principle that a drop in pressure over time is usually caused by a leak in the pipe. This test is used for larger pipelines made of DI, GRP, PVC and Steel.

The test is most accurate for Ductile Iron (DI) and Steel, since these do not continue to expand when loaded. This test is also suitable for PVC, GRP and ABS but since these nonmetallic pipelines can display some movement under load, they may require longer test duration or repeat testing.

It is not suitable for PE pipelines or for Polybutylene (PB) and polypropylene (PP) as these materials expand fast enough to affect the pressure during the test.

6.4.1 Method

After the pre-test requirements have been completed, raise the pressure steadily and smoothly to the STP.

Maintain the STP for the specified test duration by the addition of measured amounts of make-up water at regular intervals (usually every 5 or 10 minutes) over a period of at least 1 hour (2 hours is preferred and a maximum of 8 hours is recommended, although 12 hours or more can be acceptable). Measure and record the time, the pressure and the quantity of make-up water added at each top up.

Add up all the make-up water added during the time the test section has been pressurised

6.4.2 Acceptance Criteria

The test is considered satisfactory if:

- There is no failure of any thrust block, pipe, fitting or other pipeline component
- There is no visible leakage at pipe joints, flanges or other fittings
- The make-up water volume including the final make-up water does not exceed the maximum allowable quantity $V_{allowance}$ shown below.

$$V_{allowance} = 0.14 \times L \times D \times H \text{ (litres/hour)}$$

Where:

L = Length of pipeline under test (km)

D = Internal diameter of pipe (m)

H = Average value of head in the pipeline (m head)

Appendix C explains how to calculate H for a pipeline with a reasonably even grade and for a more complicated test section.

- A detailed pressure test report (including a pressure log of the test in .xls or .csv format) is submitted.

The allowable loss covers changes in pressure that are not caused by leakage, such as:

- Small temperature changes that cause an increase or decrease in the pressure;
- Small air pockets trapped at local high points, in joints and in small gaps that work their way out during the test;
- Mechanical joints moving around, changing the volume of the pipeline;
- Minor errors in timing, measurement gauges etc.

Appendix C shows the effects of grade on average test pressure for a pipeline with a reasonably even grade and for a more complicated test section.

6.4.3 Issues

PVC-U, M and O as well as GRP and ABS pipes can exhibit sufficient change under pressure to increase the volume of make-up water needed beyond the allowed volume. If so, it may be necessary to repeat the test or to use one of the non-standard tests in the Appendix.

If the second test does not meet the make-up water volume, and is more than in the first test, there is probably a leak. If the make up water is less than in the first test, a third test can be carried out.

If the third test also fails to meet the make-up requirements, and is larger than the first or second test, the line is probably leaking. If there is a clear trend of reducing volume of make-up water between each successive test, the pipeline can be considered to pass.

6.5 Testing PVC Pressure Pipelines (NZS 7643)

This section sets out a method for testing PVC pipelines above or below ground.

6.5.1 Method

A test pressure of 1.5 times the maximum working pressure of the system shall be applied over the test length and allowed to stand without make up pressure for one hour. Key areas with valves, hydrants etc shall be left exposed so any leakage can be visually noted.

6.5.2 Acceptance Criteria

The pipeline passes the test if a visual inspection shows no evidence of leaks and if the rate of pressure drop does not exceed 10 percent of test pressure per hour when allowance is made for any pressure loss due to expansion or temperature change.

6.5.3 Issues

A temperature increase causes a pressure drop since the coefficient of thermal expansion of PVC pipe exceeds that of water. A temperature increase of 1^0C will cause a pressure drop of about 3.5 kPa. The pressure drop due to temperature expansion alone is quite rapid at the start of the test, falling off to a steady rate of about 4kPa. This issue will generally only arise if the pipe is tested above ground as a buried pipeline is insulated by the fill above to maintain a relatively constant temperature during the test duration.

6.6 Retesting

The contract should tell you what to do if the initial test result is unacceptable.

In most cases, faults and leaks are located and fixed, and the test is repeated.

For larger PE pipelines that have been tested using the Pressure Decay Test the stand-down time for PE pipes is a minimum four times the original test duration. Since the original test can take 2 or more hours, this means that you usually can't do a retest on the same day. You may be required to use the more complicated M5 Reference Test for any repeat testing on PE pipelines. This test is described in Appendix E.

Appendices

Appendix A – Pressure Test Safety

Appendix B – PE Pressure Response

Appendix C – Effect of Site Conditions

Appendix D – Pressure Test Equipment

Appendix E – The M5 Reference Test for PE

Appendix A – Pressure Test Safety

Pressure testing involves higher pressures than normal operations and often includes tests on pipelines that are still partly exposed. The combination of higher pressure, reduced soil support and exposed components makes pressure testing potentially dangerous.

A-1: Precautions

Some basic health and safety precautions for pressure acceptance testing include:

- Do not air test pressure pipelines at more than 50 kPa;
- Bleed as much air from the pipeline as possible as this will reduce the severity of the sudden release of pressure if something breaks;
- Do not over-pressurise the pipeline;
- Treat every exposed section of pipe as a potential hazard. Use barriers to keep people out of trenches during testing;
- Only enter the trench when absolutely necessary. Keep clear of the end closure and ensure you have a safe escape route in case the trench starts to flood. Do not allow any other work in the trench during the pressure test;
- Keep the length of exposed PE pipe to the minimum practicable. This will minimise the effects of localised heating of the pipe;
- Do not test a PVC, GRP or DI pipeline above ground;
- Make sure that all connections are secure and that none are cross-threaded before applying pressure;
- When testing PE pipe above ground take steps to avoid the pipe being over heated by the sun;
- Use potable water or as a minimum clean water for testing water supply lines;
- Disinfect potable water pipelines before putting them into service;
- Wear appropriate personal protective equipment.

A-2: Some Near-Miss Incidents

Pressure testing with air is dangerous and is not acceptable. The stored energy in the compressed air can make end caps fly off; it can break or damage end caps and fittings; it can shatter the pipe making fragments fly off; the shock wave of the expanding air can cause serious injury as the stored energy is released explosively.

While it is almost impossible to remove all air from pipelines under test it is important to remove as much air as possible. This is in part because air can interfere with testing, including masking leaks and in part because remaining air becomes compressed during testing. The more air there is in the pipeline, the greater the risk of a serious accident.

The pictures and copy of the following press report describe a pressure test incident in July 2004 in Australia which killed one worker and injured another. Note that this was a PVC pipeline that had been fitted with an inadequately restrained end cap. The risks of this happening in a PE pipeline with a butt welded stub flange or an electro-fusion end cap are significantly lower, but there is still a risk.

PIPELINE FAILS UNDER AIR PRESSURE TEST – KILLS WORKER July 2004

Two workers had completed laying a 30 metre length of DN 300 PVC pipe along a suburban roadside. The pipe was to be tested to 690 kPa with air prior to being connected to an existing steel pipe.

As the pressure approached 690 kPa, the 70 kg temporary cap exploded from the end. One worker was killed and the other injured by the blast. Timber shoring, debris from the cap and rock was strewn over 100 metres.

Figure A1 View from pipe end towards the duct	**Figure A2 View of the repaired duct**
	

In New Zealand in 2011, a Near-Miss incident occurred when an unrestrained end cap came off a PVC pipe and crashed into a cable duct. Had a worker been in the trench they could have been killed or seriously injured. The only reason that this incident was reported was that the power cable duct and cable sheath were damaged.

In late 2012, a DN 560 PN 8 PE 100 pipeline was tested above ground to 1.5 times its rated pressure (1,200 kPa test pressure) at the insistence of a supervisor. The test method specified was the M7 (rebound) test – not really a suitable test for pipe of this diameter.

The maximum recommended test pressure for PN 8 pipe is 1,000 kPa @ 20°C. During the test, the sun raised the black pipe's surface temperature well above 35°C, thereby reducing the safe test pressure to less than 790 kPa.

The tester knew that the test pressure was too high and tried (without success) to inform the supervisor and get the pressure reduced. The pipe ruptured and a massive jet of water that could have killed or injured a passer-by resulted. The whole length of pipeline had to be completely replaced as it had been over-stretched by the pressure. Figures A-3 & A-4 show views of the pipe and the ductile burst.

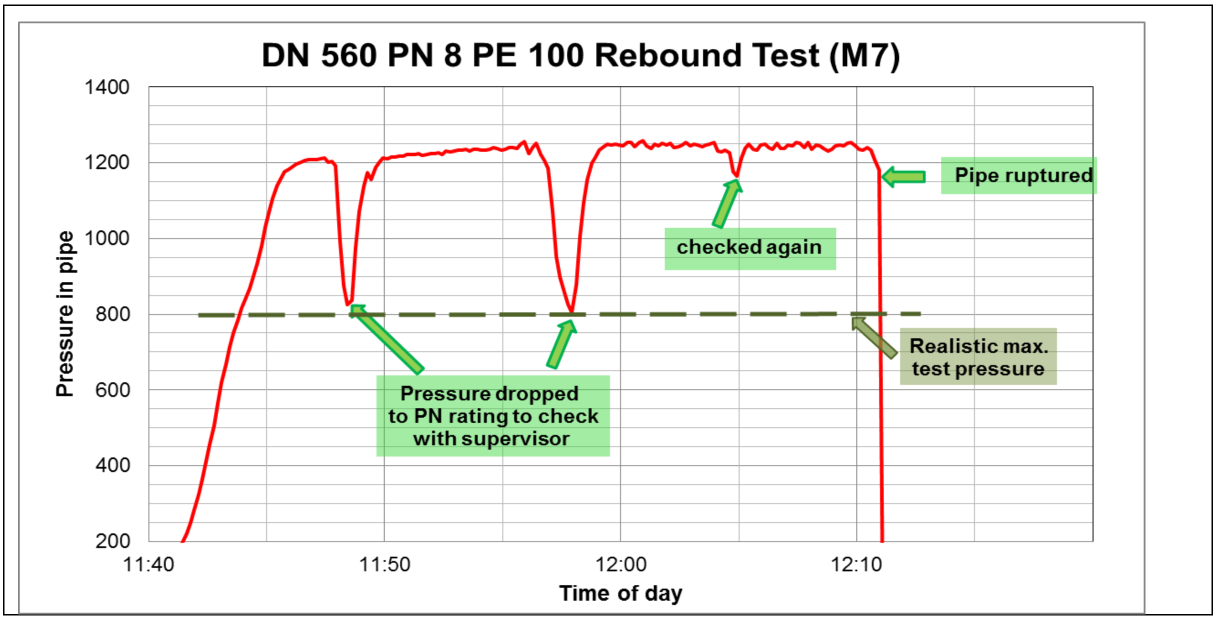
Views of the pipe above ground after the pipe ruptured. This exposed pipe was softened by the high temperature and was unable to withstand the test pressure.

Figure A-3.

Figure A-4

The test record from the pressure logger is shown in Figure A-5. Notes have been added to show the sequence of events.

Figure A-5: Pressure test readout. The M7 rebound test is not one of the standard PNCC tests.



Allowing for the higher temperature or testing on a cooler day may have prevented this failure.

Appendix B – PE pressure response

Conventional engineering materials (steel, concrete and ductile iron) are elastic materials, which means that that expand rapidly when loaded and contract quickly when the pressure is reduced. In contrast, PE takes time to respond to load so it will keep expanding when pressurised and will keep contracting long after pressured has been reduced.

Conventional (elastic) materials recover their original shape quickly after unloading. Once pressurised, the pipeline will normally stay at the test pressure. If water has to be added to maintain pressure then it usually means that there is a leak somewhere in the system. A small allowance is used to cover minor changes due to air working its way out of small gaps, and to allow for fittings moving slightly as pressure is applied.

In contrast, PE is visco-elastic so it not only stretches when first loaded but it keeps moving as long as it is under load. Also, when the load is removed from a PE pipeline there will first be a small rapid (elastic) change in size, followed by slow reduction back to the original unpressurised size over a few hours or even days.

This continued movement under load (creep) means that the pressure can drop in a pressure test because the pipe is expanding as well as because it's leaking. The slow recovery also means that after pressure is reduced, the pipe continues to contract. This compresses the remaining water causing the pressure to increase. This behaviour means that traditional pipe tests can't be used on PE pipes.

PVC, GRP and ABS also creep under load but usually the extra movement is small enough to allow conventional tests to be used with reasonable accuracy.

Appendix C – Effect of site conditions

C-1 Elevation Change Along the Pipeline

The allowable loss for a pipeline ($V_{allowance}$) with significant elevation change may be significantly less than for a pipeline that has little elevation change.

Figure C1 shows a pipeline with a uniform grade. Figure C2 shows a pipeline with an uneven grade. With an even grade (C1), the average height can be used to work out the average head, but for an uneven grade (C2), a more complicated calculation is needed.

The $V_{allowance}$ for the example in Figure C2 would be 16.5% less than for a level pipeline with an average head (H) of 100 m. For the pipeline on an even grade as shown in C1 the reduction is 7%.

For example, if we consider a DN125 (ID 0.1m) SDR11 PE80 pipe 200 m (0.2 km) long at an average head of 90 m $V_{allowance}$ for a flat gradient would be

$\boldsymbol{V_{allowance} = 0.14 \times L \times D \times H}$ (litres/hour)

0.14 x 0.2 x 0.1 x 90 = 0.252 L/hour

If we considered the topography in C2 the adjusted $V_{allowance}$ would be reduced by 100m (head on level gradient) minus 93m (average head on uniformly sloping) ground.

17% change = 0.043 L/hour

For DN900 (0.85m ID) SDR21 PE100 pipe 30 m (0.03 km) long at an average head of 20 m $V_{allowance}$ would be:

0.14 x 0.03 x 0.85 x 20 = 0.071 L/hour

Again, if we made an adjustment for the topography in C2 the reduction would be

17% change = 0.012 L/hour

These differences could mask a leak and may be the difference between a pass or fail result.

Figure C1: Average head in pipeline. (Uniform grade along the pipeline)

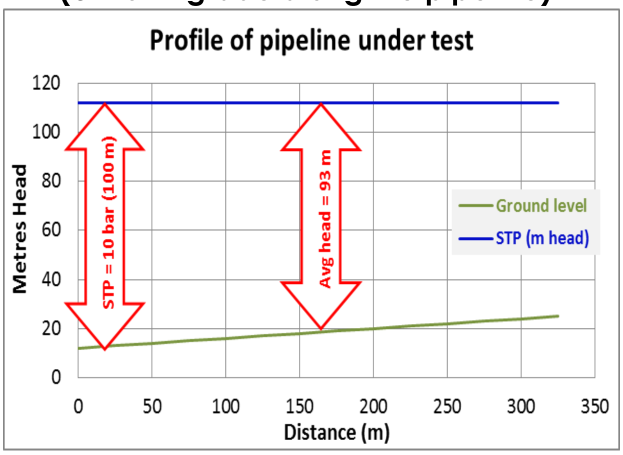
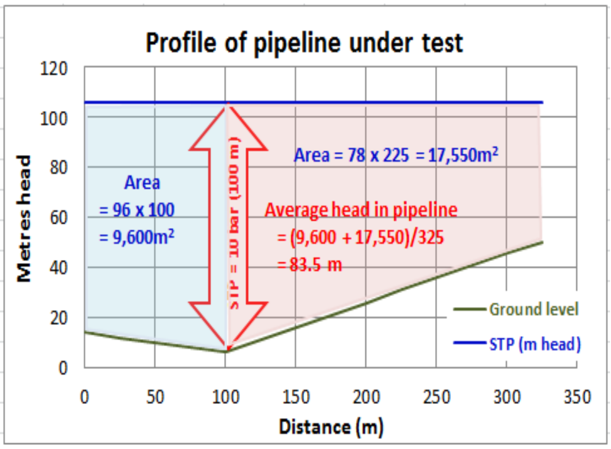


Figure C2: Average head. (Significant elevation difference)



The $V_{allowance}$ with an average head (H) of 100 m would be 20% more for the example in Figure 2-1 than in Figure 2.2. This is enough to mask a leak and may be the difference between a pass or fail result.

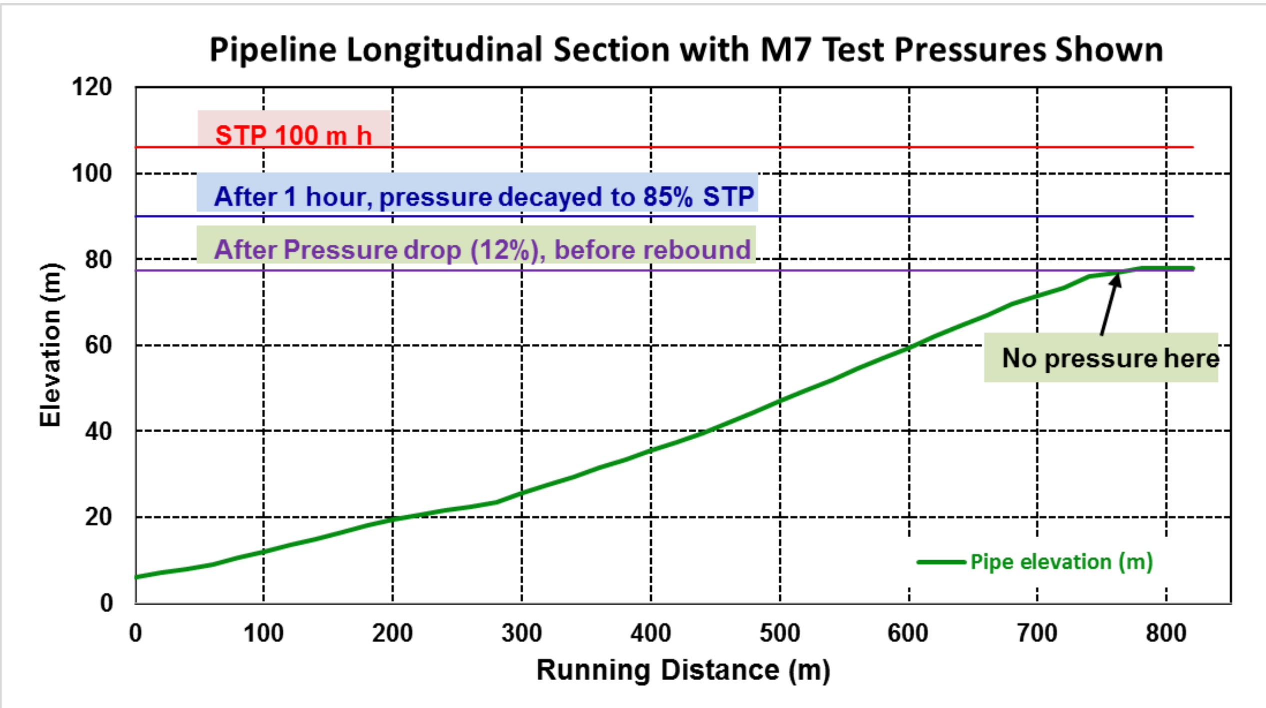
C-2 Effectiveness of Test

Table 1 shows that pressure testing is most reliable when the STP is reasonably high.

The pressure will be greatest at low points of the pipeline and lowest at local high points. Where a part of the pipeline will only see a small pressure in the test, it may be necessary to divide the pipeline into smaller more convenient test sections so that a reasonable test pressure can be applied to all parts of the pipeline. While it is possible to increase the pressure so that all parts are above a reasonable minimum pressure, this can risk over-stressing parts of the line, and local areas of low pressure may still give poor quality results.

The test pressure at the highest elevation should be at least the maximum operating pressure at that point plus 200 kPa. When there is a significant difference in elevation along the pipeline, the upper levels of the pipeline may not be given a satisfactory test. In some cases, pressure drops during the test could result in a local pressure that is only just positive or even slightly below atmospheric (Figure C3).

Figure C3: Pressure in a rising pipeline during an M7 test. The M7 test is not one of the four standard tests, but this shows how elevation affects the pressure in the pipeline.



C-3 Effect of Temperature

Temperature changes cause water and pipe materials to change size (usually they expend on heating and contract when cooled). The size change experienced differs according to the material considered, and can result in a pressure drop if the pipe expands more than the water and a pressure increase if the water expands more than the pipe.

Traditional pipeline materials need a large temperature change to make a significant difference during a pressure test, but plastics generally and PE in particular are more sensitive to temperature changes than traditional engineering materials.

While PE has a relatively high co-efficient of thermal expansion (how much the size changes as the temperature changes) the strength and stiffness can also change with temperature. These changes will affect the response of the pipe to pressure. Because of this, it is essential that variations in temperature are minimised during the test. More than 3°C change in temperature during the test period can affect the volume of the pipe enough to change the pressure and influence the test result.

Elevated temperature also reduces the pressure that PE pipes can safely withstand. If the water or pipe temperature is >23°C, the STP should be adjusted to prevent overloading the pipe, but care is needed to avoid reducing the STP so much that it affects test accuracy. Adjusting the STP is usually only needed when testing an above ground pipe in very hot conditions or when using water that has been stored in an exposed storage tank - black PE tanks in particular can get very hot in direct sunlight.

When testing during hot or sunny weather, any exposed sections of pipe will need to be shaded to minimise heat build-up. This is especially important for black or dark blue pipes which heat up more in direct sun. Black PE components in direct summer sun in very hot weather in the central South Island have been recorded reaching just over 80°C. However, even pipes in the shade or with a light coloured jacket can have significant temperature rise on a sunny day. Shading to minimise heating is particularly important for the M5 test because of its higher sustained pressure and longer duration than the M7 test. Temperature logging is recommended when temperatures are high.

Tables 2-1 and 2-2 show the maximum safe test pressure for testing PE 80 and PE 100 pipes at temperatures above 23°C using figures in PIPA document POP 103. Because PE is a poor conductor of heat, the temperature will transfer relatively slowly through the pipe wall. The pipe interior (which is filled with water) may be at a substantially lower temperature than the exterior and the net temperature effect on the pipe will be roughly the average of the water temperature and the surface temperature.

Table C2: Maximum safe test pressures for PE 80 and PE 100 pipes at elevated temperatures

Temp.	PN 8 Max (kPa)	PN 10 Max (kPa)	PN 12.5 Pipe Max (kPa)	PN 16 Max (kPa)
20	1000	1250	1563	2000
25	930	1163	1453	1860
30	870	1088	1359	1740
35	800	1000	1250	1600
40	740	925	1156	1480
45	700	875	1094	1400

Do not test when pipe temperature is greater than 45°C.

Backfilling the trench before testing helps minimise temperature variations and protects the pipeline from direct exposure to the sun. Backfilling is also a good safety precaution, as the backfill reduces the risk of components flying around if there is a burst or failure. Although backfilling is a good thing, leaving critical joints uncovered can be useful to allow inspection during the test.

In very hot weather, and especially where the pipeline is exposed to direct sun, it may be better to delay testing to cooler conditions (which could mean overnight testing or a few days' delay) rather than risk damaging the pipe or having to do repeat tests.

Section 4.2 Test Pressure, Table 2 on Page 6 shows that pressure testing is most reliable when the STP is reasonably high. The pressure will be greatest at low points in the pipeline and lowest at local high points. Where a part of the pipeline will only see a low pressure during testing it may be possible to increase the overall pressure so that all parts are above a reasonable minimum pressure.

However, as increasing overall pressure can risk over-stressing parts of the line, it may be better to divide the pipeline into smaller test sections. This way a suitable and safe test pressure can be applied to each test section.

Simple things can make a big difference e.g. allowing a pipe to stand after filling so that the water and pipe temperature have time to stabilise and shading pipes from direct sunlight where they can't be backfilled before testing.

Appendix D - Test Equipment

D-1 End Caps

These must be securely fixed to the ends of the pipeline. Any joints that do not have end-load resistance against the STP, need to be anchored securely against the thrust generated by the test pressure.

The flanges or end caps shall be drilled and tapped as necessary for bleeding air, pressurising the pipeline and monitoring the pressure. Tappings for pressure monitoring should be separate from the water inlet and outlet tapping so that pumping or discharge do not influence the displayed pressure. Standard test caps and manifolds can be useful.

For PE pipelines stub flanges with blank flange plates, mechanical end-load bearing caps that grip the end of the pipe or electrofused caps can be used. Some manufacturers are listed below:

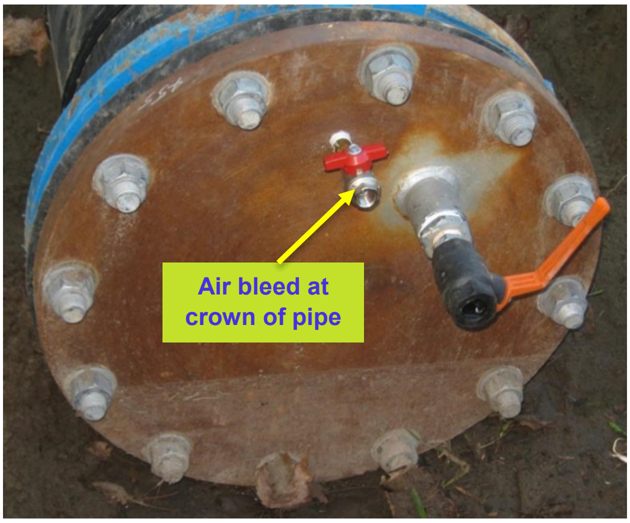
- Hawle System 2000 end caps, DN 63 – DN 315;
- GF Multijoint 3207 Plus end caps, DN 50 – DN 400;
- Viking Johnson Ultragrip end caps, DN 40 – DN 400;
- Plasson end plugs, DN 20 – DN 110;
- Philmac end caps, DN 20 – DN 63.

Many end-load resistant fittings for PE pipes rely on a stiffener or insert for their end load resistance, so it is important to check they are provided. Following the assembly instructions is particularly important for larger fittings, where installing the insert can be quite challenging.

Figures D1 and D2 show end plates on a DN 355 PE pipe with separate tappings for water inlet/outlet and pressure monitoring.

Figure D1: View of end plate and connections.

Figure D2: View of the other end plate.



D-2 Loggers and Gauges

Option 1 (preferred):

A calibrated pressure gauge. This can be either:

- a dial gauge with a dial diameter of ≥100 mm, a pressure range so that STP falls within 50% to 90% of the range, and an accuracy of ± 1% of full scale, or
- a digital gauge with a pressure range of up to 20 bar.

Either type of gauge shall be capable of being reliably read to 10 kPa or better. This gauge is used as a cross-check against the logging pressure gauge. Provided the readings are within 5% of the reading then the logging gauge results can be accepted.

A calibrated logging pressure gauge with resolution to 0.001 bar or better and a pressure range of ≤30 bar and that can be set to log at the preferred interval of 5 seconds or less.

Example digital logging pressure gauges include:

  - Crystal XP2i info@cps.co.nz
  - ADT 681 Digital Pressure Gauge webenquiry@teltherm.co.nz

Option 2:

A calibrated pressure gauge. This can be either:

- a dial gauge with a dial diameter of 150 mm, a pressure range so that STP falls within 50% to 90% of the range, and an accuracy of ± 0.5% of full scale;
- a digital gauge with a pressure range of up to 20 bar with an accuracy of ± 0.5% or better.

Either type of gauge shall be capable of being reliably read to 1 kPa or better. This gauge is used to monitor the pressure at key times and for setting the required pressure during the test.

- A datalogger and pressure transducer with or without a display option. The pressure transducer shall have an accuracy of ± 0.5% or better of full scale, a resolution of 0.1% or better of full scale and a pressure range of 20 bar. The logger shall be capable of recording the pressure at intervals of 5 seconds with date/time stamp to the nearest second. Its time clock shall be correctly set for date and time and be adjusted for daylight saving time as appropriate.

One example of a suitable datalogging unit is the AD Riley LogOr, (http://www.adriley.co.nz/news/water/water201009.htm). The LogOr can also log the quantity of water that is pumped in to the pipe and the ambient temperature. The resolution of the LogOr unit may be just marginally adequate for the purpose as it can read to 0.01 bar when an appropriate meter with a pulse output is used. Other meters may only allow reading to the nearest litre which may not be sufficiently accurate.

D-3 Meters

- The volume of water drawn off (for the M7 Rebound Test) or added at intervals (for the M5 Reference test) needs to be measured. Generally, it is preferable to use a water meter to monitor this, although for the M7 Rebound test, small volumes of water drawn off can be discharged into a calibrated container and the volume measured directly. The meter shall be sized such that the peak rate of flow does not exceed the meter's Q4 (overload flow rate) and is greater than the meters Q1 (minimum accurate flow rate). A Class 1 or Class 2 water meter to OIML R 49-2 will be satisfactory provided the flow rate metered is between Q1 and Q4. A meter with a Q3 (maximum continuous flow rate) of 2.5 m3/hr would normally be satisfactory for testing most pipelines (see Table 3-1). The rig may be set up with two meters, one for measuring water in and one for water out of the pipeline.
- Battery powered electro-magnetic flow meters will also be acceptable provided they are capable of metering the range of flows reliably and to an appropriate accuracy. Meters with a pulsed volume output may be used in conjunction with a multi-channel data-logger provided the volume resolution allows the test results to be evaluated reliably.
- For large pipelines (M5 Reference test only), the meter may need to have a Q3 of 40 m3/hr (or more), depending on the pipe diameter/length under test and the pressure pump capacity.
- Table 3-1 provides a guide to the size of positive displacement meters needed for the M7 Rebound test where the critical requirement is to drop the pressure in the pipeline by 10 to 15% within a maximum of 2 minutes. The table below allows for 60 seconds to drop the pressure. Note that if the pressure is dropped in a shorter time, either a larger meter or a reduction in test length may be necessary to ensure the meter is not damaged or its accuracy is not compromised.
- Note that the table only covers pipes up to DN 315 as larger pipes should be tested using the M5 Reference.

Table D1: Maximum length of pipeline tested to minimise risk of damaging the meter.

Meter Size	PIPE DN and MAX LENGTH TESTED (m)				
	DN 125	DN 180	DN 250	DN 280	DN 315
DN 15 (Q_3 1.5)	1100	530	280	220	170
DN 20 (Q_3 2.5)	1900	900	460	370	290
DN 25 (Q_3 3.5)	2600	1250	650	520	410
DN 40 (Q_3 10)	5500	2600	1350	1100	870

Note that there is no problem if the pressure drop takes only a few seconds, provided the rate of flow does not exceed the meters published Q_4.

APPENDIX E - The M5 Reference Test for PE

This test procedure is widely accepted as the most sensitive and reliable test for critical and large diameter PE pipelines > DN 315 and is attached for information only as it is unlikely this test will be required. It gets its name because since 2002, it has been recognised as the reference test in case of dispute about the results of other tests for PE pipelines. The Reference Test is suitable for PE pipelines of all diameters but because of the test duration it is normally only specified for pipelines of >DN 315 and for other critically important pipelines. The M5 Reference test procedures are detailed below, along with some comments and precautions. This includes an example record sheet.

E-1 Preliminary Phase

The preliminary phase of this test involves pressurising a pipeline to the specified STP and allowing it to stand for ***a minimum of 12 hours*** before testing. This is called the pre-load time. The pre-load time allows for any time-dependent movement to take place and for the pipe and water temperatures to stabilise.

The longer the pre-load time period, generally the more stable and reliable the test results. Allowing the pipeline to stand overnight usually results in a pre-load time of 15 to 24 hours, but the test can still be conducted as long as the pre-load is no more than 48 hours in total , so the test can still be conducted the following day if there are unavoidable delays.

In a leak tight pipeline the pressure in the line will drop at an ever decreasing rate during this pre-load time as the pipe expands. It can be useful to take a pressure log of this pre-load period if the logging equipment can be secured against theft or vandalism.

The key points for this test are:

- Record the pipe DN and PN rating plus any visible manufacturer's markings on the pipe;
- Record the length of pipe under test pipe. If possible, measure and record the OD and wall thickness, otherwise use the average values OD and wall thickness from AS/NZS 4130 for the pipe size and PN (nominal pressure);
- Fill in the first section of the test record in as much detail as possible, see Fig E1.

Figure E1: Pipeline details section of the Test Record

PRESSURE PIPE ACCEPTANCE TEST RECORD (M5)							
CONTRACT NUMBER:			METHOD FOR ALL PIPE DN's				
PIPELINE DETAILS							
PIPE LOCATION:	Taurus Place - Downers Yard Test pipe						
PIPE SIZE:	DN	355		PRESSURE CLASS:	PN	12.5	
LENGTH (L):	0.0305	km		INTERNAL DIA	= D (m)	0.300	
MAIN MATERIAL: (tick)		PE80B	✓	PE 100	MANUFACTURER:	RXP Ash	
$V_{allowance}$ (L in 1 hour) =	0.14* L* D* H		PIPE identification		SMPK 21660 09:11		
$V_{allowance}$ (L in 1 hour) =	0.128	litres			24.03.11 ASH		
OBSERVERS:	J Black, J Johnstone, M Carstens, K Jupp, S Potts						

- Connect the pressure recording equipment and make sure it is logging (may be done after filling the line but it's preferable to log the whole process, if possible and practicable);

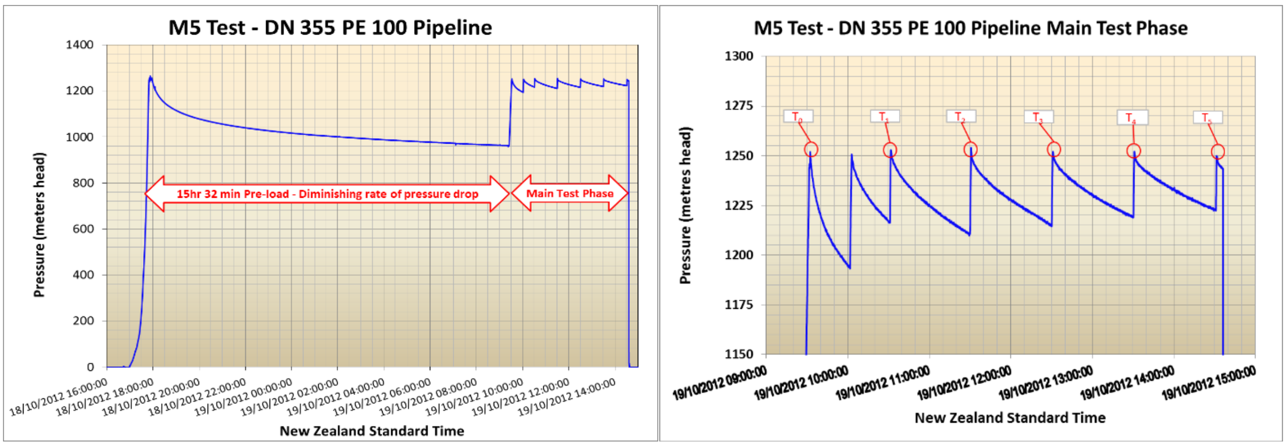
- Use a logger that can resolve the pressure to at least 0.01 bar or better and set the logging interval to 5 seconds;
- Fill the pipeline and vent as much air as possible prior to testing. Opening air bleeds and running fill water through the main will help displace the air in the line. It will also remove any debris that may be present. For larger diameter pipelines running a foam PU swab through the pipeline ahead of the fill water may be a method to remove air and debris from the pipeline;
- Raise the pressure smoothly to the STP at least 12 hours before the test. Hold the pre-load pressure for a minimum of 12 hours. Pressurising the pipeline the day before the test allows a pre-load time of 15 to 24 hours before testing;
- Use a pump with a capacity that will allow the STP to be restored accurately, without over-run. The pump size/capacity needed will depend on the size of the pipe under test and the volume of air remaining in the pipeline. If too small, it will take too long to restore pressure and if too large it may be difficult to control with the precision necessary. Take care not to exceed 1.25 times the PN rating of the pipe or any fittings or valves in the line – watch the pressure gauge at all times while the pump is running;
- Where possible and practicable, log the pressure during the initial charging of the line and pre-load period. If the logger does not have sufficient capacity to record for the full test duration at 5 second intervals, the pre-load time may be logged at 30 second intervals and the logger may be down loaded and then re-programmed to 5 second intervals before the main test phase commences;
- Record the pressure and the time and leave the pressure to decay naturally until the main test phase starts (at least 12 hours later);
- Inspect any exposed joints, valves, flanges, etc. for visible leaks;
- If the pressure drops to less than 70% of the STP after the pre-load time, a leak is highly likely;

Calculate $V_{allow} = 0.14 \times L \times D \times H$, where;

V_{allow}	=	litres make-up water allowed in 1 hour,
L	=	test length (km),
D	=	pipe ID (m) and
H	=	average pressure in pipeline (m head).

E-2 Example test plots

Figure E2: A successful M5 Reference test – full duration & main test phase.



E-3 Main Test Phase

After the pre-load period, the pressure is then returned to the STP by pumping in water at approximately the same temperature as the water already in the pipeline (within ± 3°C). The volume of water required to raise the pressure to the STP is metered and recorded. The pressure is then topped-up (back to the STP) every hour – may be several times during the hour, for 5 hours (or more if specified or required to clarify a test) and the volume of water added is metered and recorded along with the pressure for each time period.

- Take care to restore the pressure in the pipeline accurately to the STP at the end of each hour, preferably within ± 1 minute but always ± 2 minutes. The pressure top-up may be carried out during the hour but the final top-up for each hour should be as close as possible to the hour and all volumes added during the hour must be recorded and added together. Times between top-ups of 10 to 15 minutes may be the practical minimum period. Alternatively, the topping-up can be carried out whenever the pressure drops by, say, 10 kPa;
- If the pipeline is not restored reliably to the same pressure at the end of each hour or if the time varies by more than ± 2 minutes the volume of water metered will not truly reflect the amount required for the calculations – it may be less (or more) than needed. Although it is possible apply corrections to the result this must be done with care and an independent experienced person;
- Record the volume of water added to 0.1 litres (or better) using a calibrated water meter. It is acceptable to add water at intervals during each hour. If this is done regularly at, say, 15 minute intervals the operator is more likely to retain focus and is more likely to achieve the critical end-of-hour times. The volumes pumped in during the hour must be summed to arrive at the total for each hour;
- Make sure that the site record is clear and legible and that the volumes of water added and the pressures achieved at each critical point are recorded precisely;

Notes:

1) ***The water added volume should be measured and recorded to at least the nearest 0.1 Litres or V_{allow}, whichever is smaller.*** Volumes to the nearest litre are unlikely to be sufficiently accurate for most PE pipelines under test.

E-4 Acceptance Criteria

The pressure test is considered satisfactory if:

- There is no failure of any thrust block, pipe, fitting or other pipeline component;
- There is no visible leakage;
- The volume of water added during the hour between t4 and t5 is less than that added between the hour between t2 and t3 x 0.55 + Vallow;
- A detailed pressure test report (including a pressure log of the test in .xls or .csv format) is submitted.

E-5 Early Indicators of a Failed Test

There are a number of early-warning signs that the test is likely to be unsuccessful. These include:

- The pressure in the pipeline during the pre-load period does not show a pronounced continuously reduction in the rate of drop from the rapid drop at the start;
- There is no clear reduction in the pressure drop and quantity of water added each hour during the main test phase.

E-6 – M5 Reference Test Site Record Form

PE PIPE PRESSURE ACCEPTANCE TEST (M5) - SITE RECORD

TEST DATE @ START		**CONTRACT No./CLIENT**			
PIPELINE LOCATION:					
PIPE DN:		PN		LENGTH (L):	(km) D (Pipe ID (m))
PIPE MATERIAL:		PE80B		PE 100	MANUFACTURER:
V_{leak} (L in 1 hour) =		0.14* L* D* H		MANUFACTURERS ID ON PIPE	
=			litres		
TEST OBSERVER/S					
TEST INFORMATION			DATE/TIME STP ACHIEVED		
System Test Pressure STP (m head)			MEAN H(m) (If different to STP)		

NOTE: Do not exceed 1.25 times pressure of lowest rated pipeline component

PRELIMINARY PHASE - PRE-LOAD *(Allows temperature to stabilise*

1. Fit logging pressure gauge (set to ≤ 5 seconds), fill main with water and purge air. (Use safe, potable water
2. Raise to STP and pre-load for at least 12 hours (24 hours preferred). The pressure will drop during the pre-load time.
3. Check for leaks and repair as needed.

MAIN TEST PHASE

1. After preliminary phase, return pressure to STP & maintain by pumping a measured quantity every hour for 5 hrs.
2. Record time, pressure & volume added each hour for the full main phase.
3. Test is successful if: $V_{(@t5)}$ is equal to or less than 0.55 x $V_{(@t3)}$ + V_{leak}

NOTE: All pressure readings to be measured to ±0.5 kPa (or better) & the restored pressure set as accurately as possible (within ±1 kPa). If this is difficult, alter procedures to make it possible.

Date/Time @ end of pre-load		*Pressure @ end of pre-load*		*Meter reading at end of pre-load*	

	TIME	P Dropped to (kPa)	P Raised to (kPa)	Meter	Vol. added (Litres)	COMMENTS
Time, pressures & meter when STP re-established						***Start main phase (t0)***
+ 60 mins						***(t1)***
+ 120 mins						***(t2)***
+ 180 mins						***(t3)***
+ 240 mins						***(t4)***
+ 300 mins						***(t5) (Usual end)***

Was the STP achieved (within +5% - 2%?)		Yes		No

COMPARE: $V_{(@t5)}$ **& 0.55** $V_{(@t3)} + V_{leak}$ **Pass if:** $V_{(@t5)}$ **is ≤ 0.55*** $V_{(@t3)} + V_{leak}$

0.55 $V_{(@t3)} + V_{leak}$	=		litres	$V_{(@t5)}$ =		litres
Criteria met?	Yes		No			
COMMENTS:						

CERTIFIED

SIGNED:		WITNESS:	
NAME:		NAME:	

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